

Physical Aperture in LQXB01 with measured offsets

The physical aperture (or geometric acceptance) in the low and high luminosity IRs was calculated using the alignment data from LQXB01. Lattice functions and the closed orbit were obtained from LHC lattice version 6.2 at collision and from LHC lattice version 6.4 at injection. We followed the definition and computation method used in Ref.[1]. The physical aperture is calculated on the basis of the largest secondary halo that can be inscribed in the vacuum chamber, taking into account the displacement of the beam at a particular point.

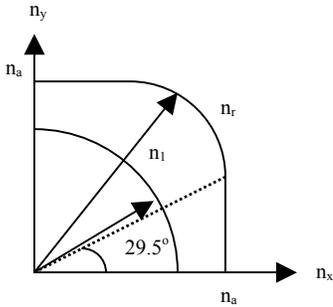


Fig. 1 The geometrical edge of the secondary halo

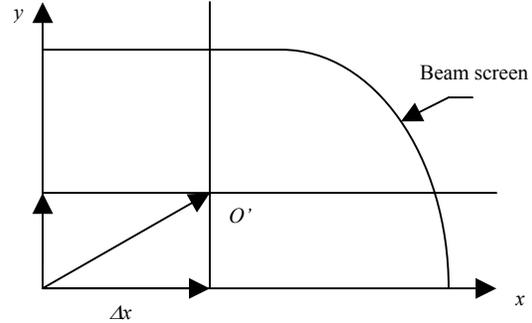


Fig. 2 Fit of the largest secondary halo in the vacuum chamber with the beam displaced by $\Delta x, y$ with respect to the ideal center of the chamber

The primary collimators of the machine are at the distance n_l in the n_x - n_y plane, and define the primary aperture. The secondary halo is defined by $n_r/n_l=1.4$, as seen in Fig. 1. The maximum beam displacement is calculated as follows (see Fig. 2)

$$\Delta_z = CO_err + abs(z_{co} + z_{offset}) + \delta_z^{align} + k_\beta \cdot D_z \cdot \delta_p, \quad z = x, y$$

where CO_err is the maximum closed orbit error taken to be 2.8mm (the value used in LHC Note 188), z_{co} is the closed orbit excursion obtained from LHC lattice version 6.2, z_{offset} is the offset of Q2 from LQXB01. $\delta_z^{align} = 1.6/\sqrt{2}$ mm is the alignment tolerance of the vacuum chamber in the plane. Here we have assumed that the probably of an alignment error is equally likely in both planes and assigned them the same weight. $k_\beta=1.1$ is beta beating coefficient, D_z is the dispersion, and $\delta_p=(1 \times 10^{-3}, 2 \times 10^{-4})$ is the rms momentum spread at (injection, collision) respectively. The secondary halo n_r is calculated from the maximum beam ellipse that can be inscribed within the aperture set by the beam screen. Beam screen size used here was obtained from Nikolai Mokhov: $x_{beamscreen}=30.1$ mm, $y_{beamscreen}=25.3$ mm for IP5 and IP8, and $x_{beamscreen}=25.3$ mm, $y_{beamscreen}=30.1$ mm for IP1 and IP2.

Tables 1 and 2 list the physical aperture (geometric acceptance) n_l in x and y plane at collision (Red color means that the aperture in this plane is smaller), and Table 3 and 4 list the physical aperture at injection, which are calculated for low luminosity IRs (IP2 & IP8) and high luminosity IRs(IP1&IP5) in three cases.

- Case 1 (the left column of Fig. 3): Q2A-Q2B axes relative to Q2a-Q2b Ave

(measured 20 Feb03, at 4.5 °K in the 2nd thermal cycle TC2, AC);

- Case 2 (the right column of Fig.3): Q2A-Q2B axes relative to SSW (measured 09 Dec02, 4.5 °K, TC1)
- Case 0: with no offset.

The offsets listed in the table are the measured data.

The related beta functions, closed orbit excursions, dispersions and calculated r.m.s beam size are also listed in the tables.

The minimum physical aperture obtained at collision in high luminosity IRs is above 9σ , which is 2σ larger than the nominal primary aperture of $n_I=7.0$. The minimum physical aperture obtained at injection in low luminosity IRs is above 8σ , which is 1σ larger than the nominal primary aperture of $n_I=7.0$.

Reference

[1] J.B. Jeanneret and R.Ostojic, Geometrical acceptance in LHC Version 5.0. LHC project Note 111, 15 September 1997.

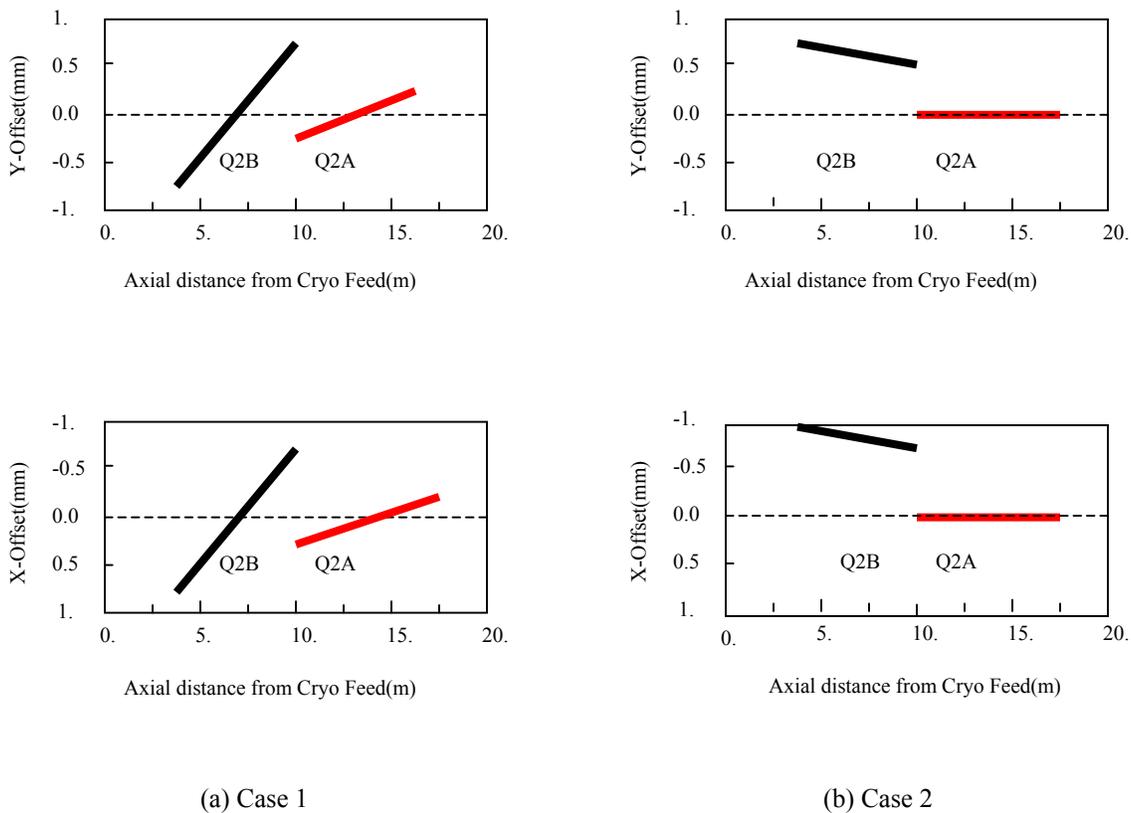


Fig. 3 LQXB01 Alignment: Q2A-Q2B axes relative to Q2a-Q2bAve (dotted line)

Right side of the IP		β_x (m)	β_y (m)	x_{co} (mm)	y_{co} (mm)	Dx (m)	Dy (m)	Case1			Case2			Case 0: No Offsets	
								Offset		n1(≥ 7 .)	Offset		n1(≥ 7 .)	n1(≥ 7 .)	
								x (mm)	y (mm)		x (mm)	y (mm)			
IP2	Beam1	Q2A(1)	197.0	58.7	1.878	-3.494	.225	.002	-.082	.106	46.2	.002	.011	46.3	46.2
		Q2A(2)	260.4	59.7	2.171	-3.583	.259	-.011	.082	-.106	39.5	-.004	.015	39.4	39.5
		Q2B(2)	265.0	67.0	2.196	-3.817	.262	-.018	-.538	.743	40.9	-.858	.727	40.2	39.1
		Q2B(1)	217.6	102.9	2.000	-4.763	.237	-.034	.538	-.743	45.9	-1.011	.922	42.4	43.6
	Beam2	Q2A(1)	58.7	197.1	-1.037	6.318	.170	-.155	-.082	.106	48.4	.002	.011	48.0	48.4
		Q2A(2)	59.6	260.5	-1.064	7.306	.164	-.183	.082	-.106	43.0	-.004	.015	43.4	43.1
		Q2B(2)	66.9	265.2	-1.133	7.389	.170	-.187	-.538	.743	38.8	-.858	.727	39.2	41.3
		Q2B(1)	102.8	217.7	-1.414	6.728	.202	-.172	.538	-.743	37.3	-1.011	.922	42.2	40.2
IP8	Beam1	Q2A(1)	198.0	58.3	6.412	0.000	.043	.038	-.082	.106	49.4	.002	.011	49.4	49.4
		Q2A(2)	261.7	59.1	7.431	0.000	.043	.053	.082	-.106	44.0	-.004	.015	43.7	44.0
		Q2B(2)	266.1	66.3	7.518	0.000	.041	.064	-.538	.743	43.3	-.858	.727	42.6	42.2
		Q2B(1)	217.6	101.9	6.845	0.000	.033	.093	.538	-.743	42.5	-1.011	.922	39.7	41.5
	Beam2	Q2A(1)	58.3	197.9	-3.545	0.000	-.134	.158	-.082	.106	50.5	.002	.011	50.2	50.5
		Q2A(2)	59.0	261.6	-3.660	0.000	-.145	.178	.082	-.106	43.9	-.004	.015	43.7	43.9
		Q2B(2)	66.2	266.0	-3.912	0.000	-.157	.178	-.538	.743	42.1	-.858	.727	42.0	43.6
		Q2B(1)	101.8	217.5	-4.911	0.000	-.202	.158	.538	-.743	46.1	-1.011	.922	46.5	48.2

Table 1. Physical aperture for low luminosity IRs at collision

Notation:

Q2A(1)/Q2B(1) represent the offsets of the far ends of Q2A and Q2B

Q2A(2)/Q2B(2) represent the offsets at the weld end of Q2A and Q2B.

Right side of the IP		β_x (m)	β_y (m)	x_{co} (mm)	y_{co} (mm)	Dx (m)	Dy (m)	Case1			Case2			Case 0: No Offsets	
								Offset		$n1(\geq 7.)$	Offset		$n1(\geq 7.)$	$n1(\geq 7.)$	
								x (mm)	y (mm)		x (mm)	y (mm)			
IP1	Beam1	Q2A(1)	1164.2	3406.2	-0.003	5.892	-0.524	0.742	-0.082	.106	11.8	.002	.011	11.7	11.8
		Q2A(2)	1264.6	4559.8	0.003	6.755	-0.546	0.858	.082	-106	10.3	-0.004	.015	10.3	10.3
		Q2B(2)	1442.2	4710.7	0.004	6.839	-0.583	0.872	-.538	0.743	9.3	-0.858	.727	9.3	9.8
		Q2B(1)	2222.7	4082.8	0.004	6.314	-0.725	0.813	0.538	-0.743	8.9	-1.011	.922	9.7	9.5
	Beam2	Q2A(1)	3403.1	1164.6	0.000	-3.383	1.548	-0.217	-0.082	.106	12.2	.002	.011	12.1	12.2
		Q2A(2)	4555.7	1265.1	0.000	-3.414	1.792	-0.228	.082	-106	10.5	-0.004	.015	10.5	10.5
		Q2B(2)	4706.5	1442.8	0.000	-3.596	1.821	-0.244	-.538	0.743	9.9	-0.858	.727	10.0	10.3
		Q2B(1)	4079.1	2223.5	0.000	-4.364	1.696	-0.304	0.538	-0.743	10.6	-1.011	.922	10.8	11.1
IP5	Beam1	Q2A(1)	1164.1	3405.8	-3.378	0.001	-0.383	-0.414	-0.082	.106	12.2	.002	.011	12.1	12.2
		Q2A(2)	1264.5	4559.3	3.409	0.002	-0.401	-0.477	.082	-106	10.5	-0.004	.015	10.5	10.5
		Q2B(2)	1442.1	4710.3	3.591	0.002	-0.429	-0.484	-.538	0.743	10.0	-0.858	.727	10.0	10.3
		Q2B(1)	2222.5	4082.4	4.358	0.001	-0.534	-0.449	0.538	-0.743	10.6	-1.011	.922	10.7	11.1
	Beam2	Q2A(1)	3403.1	1164.6	5.895	0.000	1.015	0.291	-0.082	.106	11.8	.002	.011	11.8	11.8
		Q2A(2)	4555.7	1265.1	6.758	0.000	1.175	0.302	.082	-106	10.3	-0.004	.015	10.2	10.3
		Q2B(2)	4706.5	1442.8	6.843	0.000	1.194	0.321	-.538	0.743	10.0	-0.858	.727	9.9	9.8
		Q2B(1)	4079.1	2223.5	6.318	0.000	1.113	0.397	0.538	-0.743	9.8	-1.011	.922	9.1	9.5

Table 2. Physical aperture for high luminosity IRs at collision

Notation:

Q2A(1)/Q2B(1) represent the offsets of the far ends of Q2A and Q2B

Q2A(2)/Q2B(2) represent the offsets at the weld end of Q2A and Q2B.

Right side of the IP		β_x (m)	β_y (m)	x_{co} (mm)	y_{co} (mm)	Dx (m)	Dy (m)	Case1			Case2			Case 0: No Offsets	
								Offset		n1(≥ 7 .)	Offset		n1(≥ 7 .)	n1(≥ 7 .)	
								x (mm)	y (mm)		x (mm)	y (mm)			
IP2	Beam1	Q2A(1)	191.2	59.1	2.822	-4.912	0.107	0.	-.082	.106	11.3	.002	.011	11.4	11.3
		Q2A(2)	270.1	59.7	3.291	-5.051	0.126	0.	.082	-.106	9.3	-.004	.015	9.2	9.3
		Q2B(2)	272.1	63.0	3.293	-5.203	0.126	0.	-.538	.743	9.7	-.858	.727	9.5	9.2
		Q2B(1)	211.1	106.9	2.845	-6.838	0.111	0.	.538	-.743	11.3	-1.011	.922	10.4	10.7
	Beam2	Q2A(1)	59.1	191.2	-1.405	8.718	-0.043	0.	-.082	.106	10.8	.002	.011	10.7	10.8
		Q2A(2)	59.7	270.1	-1.171	10.439	-0.037	0.	.082	-.106	9.1	-.004	.015	9.2	9.1
		Q2B(2)	63.0	272.1	-1.160	10.490	-0.037	0.	-.538	.743	8.3	-.858	.727	8.4	8.9
		Q2B(1)	106.9	211.1	-1.267	9.299	-0.041	0.	.538	-.743	8.2	-1.011	.922	9.5	9.0
IP8	Beam1	Q2A(1)	191.9	58.7	-8.721	-1.425	-0.082	0.	-.082	.106	10.8	.002	.011	10.8	10.8
		Q2A(2)	271.2	59.1	-10.410	-1.259	-0.095	0.	.082	-.106	9.1	-.004	.015	9.1	9.1
		Q2B(2)	273.1	62.4	-10.454	-1.262	-0.095	0.	-.538	.743	8.6	-.858	.727	8.8	8.9
		Q2B(1)	210.8	105.9	-9.217	-1.466	-0.084	0.	.538	-.743	8.7	-1.011	.922	9.0	9.0
	Beam2	Q2A(1)	58.7	191.9	4.882	2.854	0.049	0.	-.082	.106	11.3	.002	.011	11.2	11.3
		Q2A(2)	59.1	271.2	4.969	3.382	0.051	0.	.082	-.106	9.2	-.004	.015	9.3	9.2
		Q2B(2)	62.4	273.1	5.111	3.393	0.053	0.	-.538	.743	8.8	-.858	.727	8.8	9.2
		Q2B(1)	105.9	210.8	6.681	2.970	0.069	0.	.538	-.743	10.1	-1.011	.922	11.1	10.7

Table 3. Physical aperture for low luminosity IRs at injection

Notation:

Q2A(1)/Q2B(1) represent the offsets of the far ends of Q2A and Q2B
Q2A(2)/Q2B(2) represent the offsets at the weld end of Q2A and Q2B.

Right side of the IP		β_x (m)	β_y (m)	x_{co} (mm)	y_{co} (mm)	Dx (m)	Dy (m)	Case1			Case2			Case 0: No Offsets	
								Offset		n1(≥ 7 .)	Offset		n1(≥ 7 .)	n1(≥ 7 .)	
								x (mm)	y (mm)		x (mm)	y (mm)			
IP1	Beam1	Q2A(1)	42.2	121.4	-1.868	6.329	-0.020	0.	-0.082	.106	14.7	.002	.011	14.6	14.7
		Q2A(2)	41.9	167.1	-1.677	7.356	-0.013	0.	.082	-.106	13.0	-.004	.015	13.1	13.0
		Q2B(2)	43.8	168.8	-1.680	7.381	-0.012	0.	-.538	0.743	12.1	-.858	.727	12.2	12.8
		Q2B(1)	70.2	138.5	-1.915	6.617	-0.008	0.	0.538	-.743	11.7	1.011	.922	13.1	12.5
	Beam2	Q2A(1)	121.4	42.2	3.410	-3.805	-0.050	0.	-0.082	.106	13.7	.002	.011	13.8	13.7
		Q2A(2)	167.1	41.9	3.981	-3.730	-0.063	0.	.082	-.106	11.3	-.004	.015	11.3	11.3
		Q2B(2)	168.8	43.8	3.998	-3.799	-0.064	0.	-.538	0.743	11.8	-.858	.727	11.6	11.3
		Q2B(1)	138.5	70.2	3.600	-4.678	-0.060	0.	0.538	-.743	13.4	1.011	.922	12.3	12.7
IP5	Beam1	Q2A(1)	42.2	121.4	3.803	3.415	-0.037	0.	-0.082	.106	13.7	.002	.011	13.7	13.7
		Q2A(2)	41.9	167.1	3.723	3.999	-0.027	0.	.082	-.106	11.3	-.004	.015	11.4	11.3
		Q2B(2)	43.8	168.8	3.792	4.017	-0.026	0.	-.538	0.743	10.8	-.858	.727	10.8	11.3
		Q2B(1)	70.2	138.5	4.664	3.627	-0.023	0.	0.538	-.743	12.0	1.011	.922	13.2	12.7
	Beam2	Q2A(1)	121.4	42.2	-6.328	-1.873	-0.046	0.	-0.082	.106	14.7	.002	.011	14.7	14.7
		Q2A(2)	167.1	41.9	-7.350	-1.697	-0.058	0.	.082	-.106	13.0	-.004	.015	13.0	13.0
		Q2B(2)	168.8	43.8	-7.375	-1.703	-0.059	0.	-.538	0.743	12.5	-.858	.727	12.7	12.8
		Q2B(1)	138.5	70.2	-6.608	-1.958	-0.059	0.	0.538	-.743	12.2	1.011	.922	12.9	12.5

Table 4. Physical aperture for high luminosity IRs at injection

Notation:

Q2A(1)/Q2B(1) represent the offsets of the far ends of Q2A and Q2B
Q2A(2)/Q2B(2) represent the offsets at the weld end of Q2A and Q2B.